Meeting Summary:

National Earthquake Prediction Evaluation Council (NEPEC)

2 – 3 September 2015, Southern Methodist University, Dallas, Texas

Main topics of the meeting:

- *USGS OEF priorities, user needs, and Powell Center project plans*
- *USGS development of an operational aftershock forecasting tool*
- *Lessons learned from New Zealand and Nepal aftershock forecasting*
- *Progress in automated detection of geodetic strain transients*
- *Development of methods for forecasting and hazard in areas subject to induced seismicity*

Requests to the Council:

- *A statement from NEPEC on proper posing and testing of predictions, which can be shared with colleagues and members of the public, with recommendations on USGS & NEPEC roles.*
- *Review and endorsement of a proposed operational aftershock forecasting methodology.*
- *Recommendations on USGS development of OEF methods and products to meet user needs.*
- *Recommendations on USGS priorities in R&D and operationalization of improved forecasting.*

Summary prepared by Michael Blanpied, USGS.
Presentations & read-aheads: ftp://ftpext.usgs.gov/pub/er/va/reston/EHP/NEPEC/NEPECmtgSept2015/

Day 1 (September 2, 2015)

Welcomes, introductions, agenda, FACA guidelines (SMU, Tullis, Blanpied)

The Council and invited speakers were welcomed to Southern Methodist University by Dr. James Quick, who serves as the associate vice president for research, dean of graduate studies, and professor of earth sciences. He highlighted the strong earth science department at SMU, with a strong geophysics research group that has been monitoring and studying potentially induced seismicity in north Texas, and a growing group focused on remote sensing and earth observations led by InSAR scientist Zhong Lu (formerly at the USGS Cascades Volcano Observatory). Quick mentioned plans to create a new Center for Earth Observation, and invited USGS to consider creating a research office at SMU aligned with that center.

Status of OEF strategic planning and debate on need for OEF (Blanpied)

Presentation: NEPEC-Sept2015_01_Blanpied_Agenda&OEF.pdf
Read-aheads: N01a – USGS OEF strategic plan
N01b – NEPEC Chair letter to USGS Director in September, 2014
N02a – International Commission (ICEF) report, 2011
N02b – Jordan & Jones opinion on OEF, 2011
N03a – Peresan et al. paper critical of OEF, 2012
N03b – Wang et al. opinion critical of OEF, 2014
N03c – Jordan et al. opinion on value and principles of OEF, 2014
N03d – Kossobokov et al. opinion on OEF, 2015
N03e – Goltz on emergency management perspective on OEF, 2015

Blanpied introduced the meeting agenda and reminded members of the nature of NEPEC as a Congressionally established federal advisory committee subject to the rules of the Federal Advisory Committee Act (FACA). He then provided background on the meaning of Operational Earthquake

Forecasting, current USGS activities relating to OEF, and potential future directions for the agency. He explained that the Council would be provided with briefings on those various activities, and asked to provide recommendations to the USGS Director on priorities going forward. Current activities include development of an operational aftershock forecasting capability for the nation and the world, researching user needs for earthquake forecast information, developing effective products to communicate forecast information to meet the needs of various audiences, creating a prototype OEF system that provides continuously updates to the likelihood of earthquakes in California, and operational detection of geodetic transients that might conceivably be related to impending earthquakes.

Blanpied also explained the request that NEPEC draft a document that provides guidelines on properly conducting research on earthquake prediction, including appropriate ways to pose and test earthquake prediction hypotheses. This document should also provide recommendations to the USGS on its handling and testing of earthquake predictions. USGS plans to use those recommendations as the basis of an internal policy on such matters.

Role of OEF in the USGS strategic plan for Natural Hazards (Jones)

Presentation: NEPEC-Sept2015_02_Jones_USGS-science-strategy.pdf

Dr. Lucile Jones briefed the Council on the ways in which research and development of OEF fits into the USGS Natural Hazards Science Strategy (http://pubs.usgs.gov/circ/1383f/), a 2013 report that serves as a ten-year strategic plan for hazards programs across the bureau. (Jones co-chaired the internal USGS group that produced the report. OEF fits directly into the plan's fourth (of four) driving goals and a core responsibility of the USGS: "Effective situational awareness: Provide situational awareness to improve emergency response, inform the public, and minimize societal disruption." The plan calls upon EHP to address this goal by developing both OEF and Earthquake Early Warning (EEW).

Discussion

The Council discussed several aspects of OEF. Cliff Frohlich and Gail Atkinson argued that frequent release of fore cast information for both domestic and foreign earthquakes was needed to build familiarity with that information even when probabilities are low and uncertainties high. Peter Shearer stated that the most information gain comes from the simplest models, and that, while more complex models may offer additional insights, there is a break-even point beyond which little is gained despite more sophistication and complexity. Andy Michael countered that even our simplest forecasting models require research, offering the example of the two simple aftershock forecasting methods of Reasenberg & Jones and Agnew & Jones, which, by making different assumptions about the shape of the magnitude-frequency distribution of aftershocks, can lead to extremely different answers, especially when the mainshock strikes near a major seismogenic fault. Several in the room pointed out that these arguments support the need for a vigorous research program in earthquake forecasting and risk communication.

Aftershock forecasting following the Nepal Earthquake:

Forecasting aftershocks of the Gorkha, Nepal earthquake (Michael)

Presentation: NEPEC-Sept2015_03_AMichael_Nepal-aftershock-forecasts.pdf
Read-ahead: N04 – Reading material on Nepal aftershock forecasts

Following the M7.8 Gorkha, Nepal earthquake, the USGS was asked by USAID's Office of Foreign Disaster Assistance to develop aftershock forecasts to provide situational awareness for a region beset by great confusion and uncertainty. Andy Michael briefed the Council on how USGS responded to this request through the work of an ad hoc group of scientists with expertise in earthquake clustering statistics and risk communication. The USGS produced an initial aftershock forecast and three updates in the weeks following the mainshock. These were served on the USGS earthquake web page for the

Gorkha earthquake, and sent to a number of US officials in the United States and Nepal. Later updates were also translated to Nepali.

Forecasting for Nepal was made quite complex by widely diverse and strongly stated opinions from various Nepali, US, and USGS parties on whether aftershock forecasts would be helpful or harmful if released in Nepal, on what forecast information to provide, and via what manner of information documents. (This in addition to the complexities brought by distance and language, and by the inherent difficulty in communicating a distribution that varies with time, magnitude and location.) Ari Nathan, a diplomat at the US Embassy in Kathmandu, offered helpful advice on what information to share, and insights into how USGS information was being understood within Napal; as a result of these discussions, forecast updates grew to include more points regarding risk and consequences of potential aftershocks.

Calculations were also challenging due to a small number of aftershocks above the completeness threshold of about M5, and by a large, M7.3 aftershock that occurred on the 17th day of the sequence. The group initially used the method of Reasenberg & Jones (1989), as does the California Integrated Seismic Network following large events in California, initially using "generic" model parameters previously determined by Andy and others. They switched to an ETAS method following the M7.3 aftershock, which handles such complexities without needing to reinitialize the model.

Michael concluded with several observations exposed by the experience. These included that the USGS has no choice but to do OEF, given that US agencies and citizens participate in search, rescue and relief efforts, but that the USGS should improve its methods for doing OEF, and decide how well it needs to be done; that collaboration with local seismologists is critical, but may be possible only when some collaboration has been established beforehand; and that success in communicating to the public is challenged by differences in language, education and experience, but could be improved through training. Comments from Council members included a statement by Gail Atkinson that it is useful to tie forecasts directly into ground motion prediction, which has a more direct application to mitigation. Terry Tullis posed the question of whether ETAS is a "simple" or "complex" model in the context of Peter Shearer's earlier point.

Lessons learned from Christchurch and application to Nepal (Wein)

Presentation: NEPEC-Sept2015_04_Wein_OEF-Christchurch&Nepal
Read-ahead: N07c – Wein et al. manuscript on OEF communications

Anne Wein briefed the Council on results of her study of the use and effectiveness of OEF messaging during the Christchurch, New Zealand sequence, and on applications of that study's insights to the Gorkha aftershock forecasts. GNS released forecast information in many ways during the sequence, learning through experience which products, formats and information were most useful and best understood. Drawing upon the New Zealand findings and the body of social science research on risk communication, Wein warned that it is easy for scientists to over-estimate the capacity of even sophisticated users to digest technical information during a stressful situation; stressed the advantage of building relationships with relevant agencies, health organization, and local authorities; and recommended that earthquake forecasts always include information about "what to do." She pointed out that prior relationships enable the USGS to include within forecasts pointers to other health and rescue organizations and others providing advice and relief.

Recognizing that few among the general Nepal citizenry would easily digest information about forecast area, time, probability and uncertainty, the USGS split its forecasts into two parts: A simple, plain-language document that provided a few statistics about expected aftershocks, background information about aftershocks, and risk information about potential effects; and a technical appendix that

provided a full table of results for various magnitudes and time frames, with information about the calculation methodology. The USGS also followed advice from Wein on providing a sense of the spatial extent of aftershock risk through the use of maps and plain-language descriptions. Context was provided by comparing the sequence to the past twenty years of seismicity in Nepal.

What earthquake forecasts are needed by users?:

Results of Powell Center user-needs workshop (Field)

Presentation: NEPEC-Sept2015_05_Field_Powell-Center-user-needs.pdf
Read-aheads: N07a – Field et al. manuscript on OEF user needs
N11 – ATC TechBrief2, guidelines for entry of damaged buildings

Ned Field, who leads the Working Group on California Earthquake Probabilities, provided results and insights from a Powell Center workshop on OEF user needs, which was convened by USGS last March. That workshop brought together representatives from a diverse and broad suite of potential users of OEF information, who were presented with a summary of current and potential abilities to provide forecast information for decision-making, and who were asked to provide perspectives from their organizations and lines of work. (A paper describing results from the workshop has been accepted for publication in Seismological Research Letters.) Attendees described a wide range of potential uses of OEF information. For most, the uses pertain to the aftermath of a major, damaging earthquake; representatives of financial and insurance companies also described the potential use of continuous OEF information in pricing catastrophe bonds and in honing reinsurance purchases to maintain acceptable financial risk.

Field identified several key user groups as potential "early adopters" who could help guide development of methods and products that meet their needs. He identified three in particular: Utility companies, especially ones like Pacific Gas and Electric that have staff with sophisticated understanding of the science; insurance and capital market companies, including the California Earthquake Authority; and official advisory councils including NEPEC and CEPEC, along with the associated decision-making entities (CalOES in the case of CEPEC). He listed several types of information that NEPEC might find valuable, including generic and sequence-specific aftershock statistics, relationship to large, recognized fault sources, and current location and rate of seismicity compared to long-term averages. Evelyn Roeloffs recalled a special NEPEC conference call convened to discuss implications of an M7.3 Aleutian earthquake that appeared to impact a recognized seismic gap, and said that the information described by Field would have been very helpful during that discussion.

Shearer asked Field to tie the performance of the UCERF3-ETAS model (see below) to the real world, for example in examining how often the model would raise probabilities to trigger the C, B and A levels of alert in the California earthquake response plan. Field pointed out that it is extremely difficult to test such models, due to the paucity of observations compared to the number of tunable features in the model. With no observations, it is difficult to say with any more certainty than intuition whether a particular model result is reasonable, and therefore how well the model is doing. Tullis pointed to earthquake simulators as helpful in guiding intuition.

Perspectives on uses and communication of hazard and risk information and products (Wein)

Presentation: NEPEC-Sept2015_06_Wein_OEF-uses&products.pdf
Read-ahead: N07b – Becker et al. conf. paper on Canterbury OEF

Wein reviewed the various OEF products released by GNS during the Canterbury/Christchurch sequence, and how well they worked in communicating information to users. Some information was used by government and private sector for decision-making, and she was told in post-sequence interviews that more would have been used had the users had (and understood) key information

products. Examples of uses included government taking OEF information into account when sizing response work force, comparing replacement versus repair options for underground infrastructure, a building owner delaying replacement of ceiling tiles until likelihood of further shaking decreased, and members of the public reporting having been reassured by learning that the aftershock sequence was proceeding as expected. Intermediate- and long-range forecasts were considered when increasing building standards (a sobering point being that there was increasing pressure to relax those codes when the aftershock rate fell, even when the models showed that the hazard would remain well above background for decades).

Additional potential uses include safety guidelines for entering damaged buildings (e.g., ATC-35 and TechBrief 2), and better management of cordons. An important finding for the USGS is that the "STEP" hazard map was not found to be useful, because the 24-hour time frame does not show evolution of hazard, and the public was not making daily mitigation decisions. Wein concluded by pointing again to the need for communication with users to improve the effectiveness of earthquake advisories. This is embodied in guidelines for OEF product development published by Suzanne Perry and others in 2015. She also noted the importance of being open (and being perceived to be open): New Zealand citizenry were angered when sensing that information was being withheld. As has been shown in social science studies, openness does not cause panic, and is the best strategy for reassuring the public and fostering appropriate mitigation actions.

Research on and testing of predictions:

CSEP & CISM – Center for Interseismic Simulation and Modeling (Jordan)

Presentation: NEPEC-Sept2015_07_Jordan_CSEP&CSIM.pdf
Read-ahead: N10 - Memo from Tom Jordan to NEPEC

Dr. Tom Jordan, Director of the Southern California Earthquake Center at USC, briefed the Council by phone on two organizations managed by SCEC: the Collaboratory for Study of Earthquake Predictability (CSEP) and the new Collaboratory for Interseismic Simulation and Modeling (CISM, pronounced "seism"). He stressed the relevance of both activities for the USGS, and encouraged USGS participation in both, and continued financial support of CSEP. In discussion, Jordon fielded questions regarding the applicability of CSEP testing to global models (which he said was appropriate given sufficiently fine model grids), and on how much is gained by moving to more complex models, a subject being actively explored within CSEP by comparisons between empirical, physics-based, and hybrid forecast models.

Day 2 (September 3, 2015)

Ethics rules for Special Gov't Employees and protection from liability (Baumgartner)

Presentation: NEPEC-Sept2015_08_Baumgartner_Ethics-guidelines.pdf

Nancy Baumgartner, who heads the USGS Ethics office, briefed the Council on rules governing member roles and responsibilities as members of a federal advisory committee, and on legal protections that exist for Special Government Employee (non-USGS) and Regular Government Employee (USGS) members.

Aftershock forecasting:

Updated method for forecasting aftershocks (Hardebeck)

Presentation: NEPEC-Sept2015_09_Hardebeck_Aftershock-forecasting.pdf

Dr. Jeanne Hardebeck has led an internal USGS effort to update, improve and expand the agency's ability to provide earthquake advisories during aftershock sequences. This has been done routinely by the California Integrated Seismic Network (CISN, includes USGS) for some decades, using the stochastic parametric model published by Reasenberg and Jones in 1989 (R&J). The group was charged with examining the methodology, expanding its applicability to earthquake sequences anywhere in the United States or the world, and create a plan for integrating the software with the Comcat and Product Distribution Layer, which serve catalog data and derived products, respectively. They have: (1) developed Java code for calculating aftershock probabilities using either "generic" (regionally average) parameters or sequence-specific parameters that may be determined and updated as aftershocks are recorded, (2) analyzed catalog seismicity in order to tabulate "generic" parameters (a, b, p and c) for each the tectonic region types identified by Garcia (2012), (3) created software that can fit aftershock data in order to update the productivity parameter a, and (4) begun the process of integrating the method into the operations of the National Earthquake Information Center (NEIC).

Hardebeck showed examples of the model's performance when applied to the Napa and Gorkha earthquake sequences. She pointed out that the R&J methodology works well only for relatively straightforward mainshock-aftershock sequences, but is less useful during seismic swarms or following particularly large aftershocks (which themselves may generate felt aftershock sequences). It also lacks information about the spatial distribution of likely aftershocks, and guidance on potential triggering of nearby faults.

Discussion: NEPEC endorsement of aftershock forecasting methodology

The Council engaged in a vigorous discussion of issues raised by Hardebeck. Key questions included whether the Reasonberg and Jones method has been adequately tested, and whether the USGS should instead use an ETAS-based method that avoids the shortcomings listed above. Opinions were split on whether the ETAS methodology is sufficiently vetted for use in an operational product.

The NEPEC provided the USGS with two recommendations at the conclusion of this discussion. These will be formally communicated through a letter to USGS Director along with other recommendations regarding USGS OEF activities:

1) Proceed apace with implementation of an aftershock warning capability based on R&J, in order to have capability to provide forecasts outside of California.

2) Develop an alternative methodology based on ETAS, that can be expected to replace the R&J calculator once it is sufficiently tested and has received approval from NEPEC.

Developing a full rupture forecast model that includes spatiotemporal clustering:

Development of UCERF3-ETAS (Field)

Presentation: NEPEC-Sept2015_10_Field_UCERF3-ETAS.pdf

Field again briefed the Council, this time on developments of an end-to-end system to forecast earthquake occurrence, hazards and losses in California. The foundation for the system is the UCERF3 model, which provides the long-term rate and magnitude of a comprehensive suite of earthquake ruptures for the state, both on and off >300 modeled faults. A time-independent implementation of UCERF3 served as the California earthquake source model for the USGS's 2014 update to its National Seismic Hazard Maps, and a time-dependent implementation was delivered to the California Earthquake Authority for use in determining insurance premiums. Field and colleagues are now coupling the UCERF3 sources to an ETAS-based clustering model, in order to create a model capable of providing a full earthquake rupture forecast that includes aftershocks and can evolve on time scales ranging from minutes to years. The system, once completed, can produce frequency-magnitude distributions of

earthquakes on a fault or in a region, full sequences of earthquakes to include both primary and secondary aftershocks and remote triggering, and probabilistic loss distributions. The software system is largely built and is in a testing phase.

Two primary and related challenges are how to tune the many model parameters, and to test its forecasts. Field showed examples of model outputs that appear reasonable, but we lack data with which to test that intuition. He also showed examples of outputs that appear problematic, but we lack observations to guide improvements to the model or parameter choices. Additional challenges include how to best incorporate elastic rebound, which is clearly required to prevent repeating ruptures of a fault section, and how to run the model operationally when natural fault structures are so poorly known, especially at depth. These points led into a discussion with the Council on whether such models can ever be sufficiently tested to be considered appropriate for guiding decision-making. The sense of the NEPEC is that the research is worthwhile, but that it will take at least several years before an operational implementation should be considered.

Induced seismicity hazard

North Texas seismicity and induced seismicity science (DeShon)

Presentation: NEPEC-Sept2015_11_DeShon_North-Texas-seismicity.pdf

Dr. Heather DeShon of the SMU Earth Sciences Department explained recent trends in seismicity in North Texas and the work she and her colleagues have been doing to monitor and analyze the seismicity, and to test its relationship to oil and gas production and wastewater disposal operations in the region. The latter subject remains highly controversial and political in Texas. The Texas Railroad Commission, which regulates the industry, has not concluded that any of the region's seismicity is anthropogenic. In the meantime, city governments of Dallas and some of its suburbs have created a Dallas County Earthquake Working Group, which meets monthly along with representatives from FEMA, USGS, SMU, Texas DOT, and others. SMU has briefed that working group frequently on the ongoing seismicity. USGS and FEMA have delivered material regarding the likelihood and impacts of damaging earthquakes striking within the metro area, to aid city emergency managers to better understand the likely impacts and the resources that would be needed to respond should such an event occur. DeShon also provided an update on the TexNet, a seismic network funded by the Texas legislature that will be managed by the Bureau of Economic Geology at UT Austin. That network will include both fixed and portable stations, and funds are also provided for research, with the expectation that a report will be available within less than two years.

Induced seismicity hazard, one-year hazard map (Moschetti)

Presentation: NEPEC-Sept2015_12_Moschetti_Induced-seismicity-hazard.pdf
Read-ahead: N08 – Incorporating induced seismicity into hazard maps (USGS OFR)

Dr. Morgan Moschetti of the USGS national seismic hazards group in Golden, Colorado explained efforts at USGS to create a hazard model for areas of the central US that have experienced sharp changes in seismicity rate believed liked to industrial activity. The USGS identified 17 such areas, and excluded the suspect earthquakes from analysis for the 2014 national seismic hazard map update, the rationales being that such time-varying seismicity violated the assumptions of stationarity that underlie the national hazard model, and that it was not wise to provide long-term forecasts based on seismicity rates that may vary due to changes in industrial activity. The USGS has published an open-file report that shows the proposed methodology to be used to create a set of hazard maps early in 2016, which will forecast hazard for the coming 12 months only. A strong desire for such maps was expressed by attendees of a 2014 workshop hosted by USGS and the Oklahoma GS, making this a prime example of creating an operational earthquake forecast that responds to user needs. Discussions are ongoing with

the above-mentioned Dallas area working group and others, to identify what information products would be most useful.

Induced seismicity hazard in Canada (Atkinson)

Presentation: NEPEC-Sept2015_13_Atkinson_Induced-seismicity-Canada.pdf

British Columbia has experienced significant volumes of seismicity related to oil and gas production and wastewater injection. Gail Atkinson showed that this seismicity shows a similar time history to that in the central US, of acceleration matching well with the upswing in industrial activity in the region that increased sharply since about ~2008. A key difference from US observations is that 60% of the seismicity is associated with hydraulic fracturing (HF), fewer with fluid disposal, although the percentage of suspect HF wells (0.4%) lower than that of suspect disposal wells. She also showed the case of a recently exploited field at Crooked Lake, Alberta, where there was an abrupt increase in seismicity beginning in 2013. In that case between 1% and 10% of HF wells appear to be related to the observed seismicity.

Atkinson showed calculations (submitted for publication) of ground shaking hazard for such areas. She demonstrated that the hazard associated with the induced events can easily exceed the natural background hazard in the near field, due to the high rate and shallow source depth of such earthquakes. She closed with some thoughts on the best ways to model induced seismicity hazard, and on the challenges of trying to anticipate and mitigate that hazard. A key unanswered question is to what extent and over what areas wells collaborate in increasing formation fluid pressure. Atkinson pointed to her recent publication in

Discussion of induced seismicity and related hazards

In discussions following the two previous talks, Cliff Frohlich argued the importance of the smoothing parameter used in the model, as that parameter, for example, would affect how much hazard would be calculated for Dallas, given earthquake swarms in distant suburbs. He also raised the question of whether the hazard calculation methodology was too "green" to use—pointing to the earlier discussion of ETAS (a method which has been in the literature for many years), which NEPEC felt needed more research before using. Andy Michael commented that NEPEC was not briefed on the source model to be used in the 12-month hazard calculations—arguably the part of that effort that falls within NEPEC's jurisdiction), and said that the project's source model based on various extrapolations of recent seismicity performed poorly in retrospective tests. Gail Atkinson suggested that the modelers restrict themselves to using GMPE's that perform well at short distances. She also suggested decreasing the minimum magnitude of calculated earthquakes, due to induced seismicity being shallower and thus able to induce larger ground motions.

Looking ahead – forecasting capabilities and USGS priorities

Geodetic transient detection (Roeloffs, Murray by phone)

Presentation: NEPEC-Sept2015_14_Murray_geodetic-trans-detect.pdf

The USGS is conducting research on methods for automatically detecting strain transients via GPS and borehole strainmeters. The Council was briefed on these efforts as examples of research that could conceivably contribute to an OEF capability in the future.

Dr. Jessica Murray, coordinator of geodetic work within the USGS Earthquake Hazard Program, spoke on these topics, assisted by Evelyn Roeloffs. She presented results from the work of a Technical Activity Group (TAG) organized within SCEC, which she has helped lead. Researchers in that group were challenged to develop GPS transient detection algorithms for California, evaluate their

performance in blind tests, and implement the most promising algorithms for prospective testing in CSEP. Several models show promise, but only one has been considered mature enough to initiate testing: a model based on Principal Component Analysis by Tom Herring's group at MIT. Also, a method by John Langbein, based on parametric fitting to GPS time series, is running in a test mode at USGS. Challenges in this area of research include how to constrain the values of many tunable model parameters, and how to connect detected transients to changing levels of seismic hazard. Murray pointed out that an operational system would likely combine several methods, and that rigorous prospective testing is needed before models could be operationalized.

For Cascadia, Roeloffs has been analyzing the data from PBO borehole strainmeters. She has shown that those data, while complex and challenging to interpret, contain strain signals relating to slow-slip events on the subduction interface, and can be used to place bounds on those slow-slip sources. She pointed to a paper by herself and Nicholas Beeler that explores how one might connect such strain transients to a time-varying level of seismic hazard, and what features might best indicate a dangerous condition.

Discussion: USGS priorities in OEF

Read-ahead: N06 - Draft NEPEC statement on posing and testing predictions
Read-ahead: N09 – Cascadia potential forewarnings (USGS OFR)

The concluding discussion of the meeting focused on the overall OEF program within USGS. Terry Tullis stated that it is important that the USGS continue to do research and development in earthquake forecasting. Several members reiterated their support for the USGS continuing its work to implement a robust aftershock forecasting system and update its calculation engine as improved methods become available. There was also some discussion about OEF jurisdiction: for example, which country has authority to speak of earthquake probabilities in the Canadian and Mexican border regions.

The Council was provided with brief, oral updates on some items of ongoing interest, including QuakeFinder's progress toward engaging in prospective testing of their magnetometer-based earthquake prediction method, and publication of a report on potential situations in Cascadia that would raise concern among the scientific community.

Blanpied reiterated the charge to NEPEC to respond with two reports: A statement on how to properly conduct research and testing of earthquake prediction methods with recommendations for the proper roles and procedures of the USGS, and a letter to the Director that provides recommendations relating to the broader suite of OEF research, development and implementation activities. The Council identified five members interested in working together to improve a draft for the first of these documents, which would then be shared with the full committee before being transmitted to USGS.

Attending:

NEPEC:
Terry Tullis, Brown University (Chair)
William Leith, USGS, Reston (Co-chair)
Ramon Arrowsmith, ASU (not attending)
Gail Atkinson, University of Ontario
Roland Bürgmann, UC Berkeley (by phone)
Cliff Frohlich, Univ. of Texas, Austin
Susan Hough, USGS, Pasadena
Andrew Michael, USGS, Menlo Park
Evelyn Roeloffs, USGS, Vancouver, WA
Allan Rubin, Princeton University
Peter Shearer, Univ. of California, San Diego
John Vidale, University of Washington
Michael Blanpied, USGS (Secretariat/DFO)

SMU:
James Quick
Heather DeShon
Beatrice Magnani
Brian Stump

SCEC/USC:
Tom Jordan

USGS:
Nicholas Beeler, Menlo Park (by phone)
Nancy Baumgartner, Reston
Edward (Ned) Field, Golden
Jeanne Hardebeck, Menlo Park (by phone)
Stephen Hickman, Menlo Park
Lucile Jones, Pasadena
Morgan Moschetti, Golden (by phone)
Jessica Murray, Menlo Park (by phone)
Anne Wein, Menlo Park